Opinion

# Reintroducing resurrected species: selecting DeExtinction candidates

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**Technological advances have raised the controversial prospect of resurrecting extinct species. Species DeExtinction should involve more than the production of biological orphans to be scrutinized in the laboratory or zoo. If DeExtinction is to realize its stated goals of deep ecological enrichment, then resurrected animals must be translocated (i.e., released within suitable habitat). Therefore, DeExtinction is a conservation translocation issue and the selection of potential DeExtinction candidates must consider the feasibility and risks associated with reintroduction. The International Union for the Conservation of Nature (IUCN) Guidelines on Reintroductions and Other Conservation Translocations provide a framework for DeExtinction candidate selection. We translate these Guidelines into ten questions to be addressed early on in the selection process to eliminate unsuitable reintroduction candidates. We apply these questions to the thylacine, Yangtze River Dolphin, and Xerces blue butterfly.**

## DeExtinction and conservation

Technological advances have opened up the possibility of species DeExtinction, the recreation of once-extinct species [1]. The potential for DeExtinction burst upon the public scene in March 2013 at the TEDxDeExtinction conference (http://tedxdeextinction.org). Associated meetings proposed DeExtinction candidate species (Table 1), debated criteria for their selection, and discussed the pros and cons of this new conservation approach. Although the prospect of recreating woolly mammoth (*Mammuthus primigenius*), Tasmanian tigers (*Thylacinus cynocephalus*), and passenger pigeons (*Ectopistes migratorius*) among others, generated excitement in some circles [2], it was not greeted with unanimous enthusiasm ([3–5]; http://www.salon.com/).

Although concerns have been raised against DeExtinction [6,7], there is a sense that inevitable technological development means that extinct species will be resurrected at some future point [8]. However, not all DeExtinction candidates would enrich extant ecosystems without the potential for harm. Key questions are whether DeExtinction can assist conservation efforts, and what might be the relative risk and benefits of species resurrections. To be proactive, it becomes an obligation for conservation biologists to help guide decisions about which species are better candidates for revival [as discussed by Kate Jones (http://longnow.org/revive/tedxdeextinction/why-and-why-not-is-a-matter-of-specifics/) and Stanley Temple (http://longnow.org/revive/tedxdeextinction/de-extinction-a-game-changer-for-conservation-biology/)]. Here, we make the case that, where the stated primary motivation for species resurrection is to restore free-ranging populations, decisions need to be made about where to release them and what the risks or uncertainties are of doing so. As argued by Jorgensen [9], DeExtinction is a conservation translocation issue; thus, any selection of candidate species must consider the feasibility and risks of reintroduction.

Our aim is to translate relevant sections of the 2013 IUCN Guidelines on Reintroductions and Other Conservation Translocations (hereafter IUCN Guidelines) [10] into a framework of questions to be addressed during the early stages of DeExtinction candidate selection. These questions provide a filter to identify critical information gaps, uncertainties, and risks relating to the release of resurrected species, to enable early elimination of unsuitable candidates and avoid wasted effort. This 'first cut' exercise would set up a more in-depth evaluation of likely candidate species.

## DeExtinction as a conservation translocation issue

The prospect of being able to resurrect extinct species captures the imagination of many scientists and the general public alike. Inevitably thoughts turn to which species one might like to see come back to life and, unsurprisingly, given the clear taxonomic biases already evident [11], some of the wish lists emphasize species that are iconic, beloved, and missed. However, restoration of an extinct species is not a trivial matter to be focused on single charismatic species while extant species are at risk of extinction [3]. To have any credibility, the business of DeExtinction must have loftier goals than mastery of the daunting technical aspects.

Some view DeExtinction as a 'quest for redemption', a 'moral imperative' [12] to right past wrongs, to reverse species extinctions caused by humans [13]. Consequently, the goal must be more than (just) successful production of

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**Table 1. Faunal DeExtinction candidate species[a,b]**

| Common name(s) | Scientific name | Region | Extinction |
|---|---|---|---|
| Passenger pigeon | *Ectopistes migratorious* | North America | 1914 |
| Carolina parakeet | *Conuropis carolinensis* | Eastern USA | 1918 |
| Cuban red macaw | *Ara tricolor* | Cuba | 1864 |
| Ivory-billed woodpecker | *Campephilus principalis* | Southeastern USA | (1944) |
| O'o | *Moho nobilis* | Hawai'i | 1934 |
| Elephant bird | *Aepyornis* sp/*Mullerornis* sp | Madagascar | (1800s) |
| Moa | *Dinornis* spp. | New Zealand | (1400s) |
| Huia | *Heteralocha acutirostris* | New Zealand | 1907 |
| Dodo | *Raphus cucullatus* | Mauritius | 1662 |
| Great auk | *Pinguinis impennis* | North Atlantic coasts | 1852 |
| Auroch | *Bos primigenius* | Europe, Asia, North Africa | 1627 |
| Pyrenean ibex, Bucardo | *Capra pyrenaica pyrenaica* | Iberian Peninsula | 2000 |
| Thylacine, Tasmanian tiger | *Thylacinus cynocephalus* | Tasmania, Australia | 1936 |
| Woolly mammoth | *Mammuthus primigenius* | Northern steppes | (6400 yr before present) |
| Mastodon | *Mammut* spp. | North and Central America | (10 000 yr before present) |
| Saber-toothed cat | *Smilodon* | North America | (11 000 yr before present) |
| Steller's sea cow | *Hydrodamalis gigas* | North Pacific | 1768 |
| Caribbean monk seal, | *Monachus tropicalis* | Caribbean | 1952 |
| Baiji, Chinese river dolphin | *Lipotes vexillifer* | Yangtze River, China | 2006 |
| Xerces blue butterfly | *Glaucopsyche xerces* | San Francisco, USA | 1941 |

[a]See http://www.longnow.org.

[b]Extinction dates represent the death or last confirmed sighting of a living specimen, although the date of the official declaration of extinction may differ from this; dates in brackets indicate some uncertainty over the last confirmed sightings.

members of an extinct species to be sustained in a laboratory or as a zoo menagerie reminiscent of colonial times. The goal of DeExtinction should be 'deep ecological enrichment' (http://www.longnow.org), interpreted as the restoration and enhanced resilience of ecosystems in the face of changing environmental conditions [14]. Extinction of large consumers can have significant impacts on ecosystem functioning [15]. Thus, restoration of ecosystems will require the restoration of species able to perform those vital ecological functions that may have been missing as a result of extinction (e.g., mammoth steppe, the vast areas of semi-arid grassland and associated grazing megafauna that dominated North America and Eurasia at the end of the Pleistocene [16,17]). This is particularly important in situations where there is no appropriate ecological replacement [e.g., New Zealand moa (*Dinornis* sp.)] [18]. To achieve this with resurrected species requires restoration of viable, free-ranging populations through translocation into existing or recoverable ecosystems.

The fundamental criteria for selecting appropriate DeExtinction candidates for conservation aims match selection criteria to reintroduce extant species [19]. The IUCN Guidelines provide guidance on the justification, design, and implementation of any conservation translocation [10]. The Guidelines recognize that translocation can be an effective conservation tool, but one that carries multiple risks of failure, to the focal species, to the recipient ecosystem, and to human concerns. Where risk is high or there is high uncertainty about risks and impacts, decision makers may choose not to proceed with a translocation. Components of the IUCN Guidelines help in determining the level of risk and uncertainty and can be used for a first-stage evaluation of the feasibility of translocating a resurrected species. DeExtinction at its heart is a conservation translocation issue [9] and it is appropriate that the IUCN Guidelines form a basis for the selection of appropriate DeExtinction candidates [20].

## Defining translocations of resurrected species

The IUCN Guidelines set out a typology of translocations to enable practitioners to position proposed projects according to accepted definitions. It is assumed that the intentional movement and release of members of a resurrected species would constitute a conservation translocation [10] primarily for conservation benefit, in relation to the focal species or to restoring ecosystem functions or processes.

If the chosen release area sits within the indigenous range of the species, defined as the known or inferred distribution generated from historical records or physical evidence [10], then the translocation is a reintroduction, irrespective of the amount of time that has passed since last occupancy. Duration of absence from the indigenous range does not affect classification of a translocation as a reintroduction, but can increase the likelihood of significant changes in habitat suitability since extinction. Defining a translocation as a reintroduction does not remove the need for detailed assessment of release area habitat suitability [21].

Restoration of DeExtinct species need not be a reintroduction, but might constitute a conservation introduction if releases take place outside the indigenous range for conservation benefit. The IUCN Guidelines recognize two types of conservation introduction (assisted colonization and ecological replacement) depending on the status of suitable habitat and the *a priori* goals of the releases [10]. Conservation introduction of resurrected species is most likely to be considered assisted colonization, where the primary aim would be to prevent (re)extinction of a resurrected species due to the absence of suitable habitat or presence of threats in its indigenous range.

**Table 2. Components of the 2013 IUCN Reintroduction Guidelines [10][a]**

| IUCN reintroduction guideline component | | DeExtinction candidate selection |
|---|---|---|
| **Definition and classification** | | ✓ |
| **Past, current and future threats** | | ✓ |
| Planning | Goals, objectives and actions | [b] |
| | Monitoring program design | [c] |
| | Exit strategy | ✓ |
| Feasibility and design | Biological feasibility | ✓ |
| | Social feasibility | ✓ |
| | Resource availability | [c] |
| Risk assessment | Risk to source populations | [d] |
| | Ecological risk | ✓ |
| | Disease risk | ✓ |
| | Gene escape | [e] |
| | Socioeconomic risk | ✓ |
| | Financial risk | [c] |
| Release and implementation | | [c] |
| Monitoring and management | | [c] |

[a]Ticks indicate those aspects that should be applied to the first stage of DeExtinction candidate species selection.

[b]It is assumed that the translocation of any resurrected species has as its primary goal some conservation benefit gained through the restoration of a free-ranging population or populations. The goal should be stated explicitly before further candidate assessment takes place, but is not considered in detail here.

[c]Release, implementation, monitoring, and management, and availability of resources to undertake the translocation concerns arise only after a candidate species has been selected.

[d]Release of resurrected species does not entail a harvest of either captive or wild extant populations; therefore, risk to source populations does not apply.

[e]The risk of gene transfer to extant populations does not exist because a resurrected species has no extant wild populations.

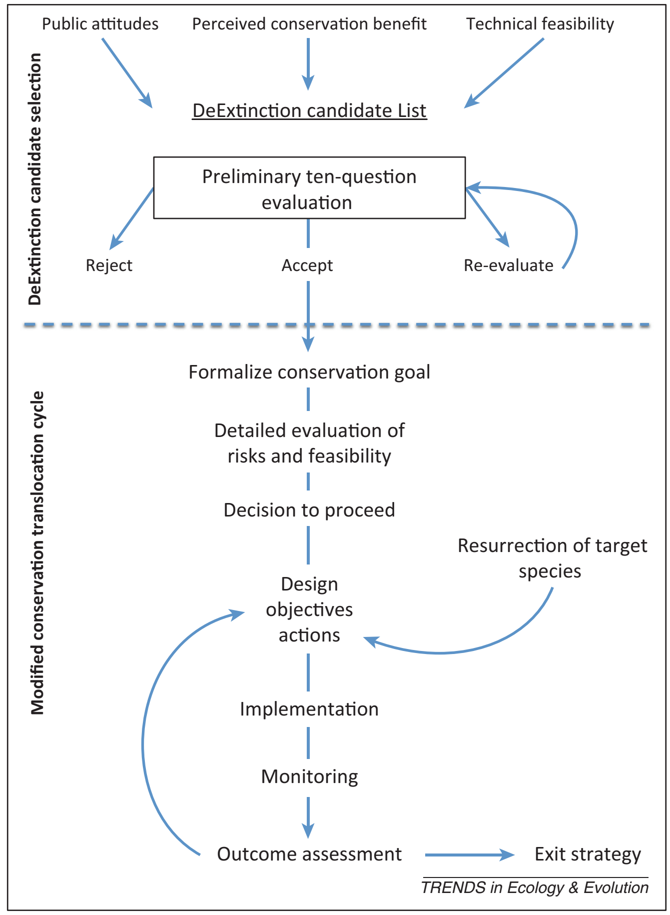


**Figure 1**. DeExtinction candidate selection and translocation flowchart Bolded items in the explanatory text below relate to headings in the flowchart. It is assumed that this process is driven principally by a **perceived conservation benefit**, as opposed to the resurrection of extinct species for medical experiments, captive menageries, or entertainment, although **public attitudes** and **technical feasibility** will also influence any **DeExtinction candidate list**. Application of the **preliminary ten-question evaluation** of DeExtinction candidate species should occur early during the planning process to eliminate clearly unsuitable candidates. Following preliminary acceptance, the proposed translocation of a given candidate would then be subject to **detailed evaluation of risks and feasibility**. Ideally, resources would not be expended in species resurrection until a **decision to proceed** had been reached; realistically, however, progress towards resurrection of the target species could proceed while the more in-depth assessment takes place as part of the **conservation translocation** cycle. Modified from 2013 International Union for the Conservation of Nature Guidelines on Reintroductions and Other Conservation Translocations.

## Applying the IUCN Guidelines to DeExtinction candidate species selection criteria

We use the template of the IUCN Guidelines as the basis for *a priori* evaluation of DeExtinction candidate species. Some components of the IUCN Guidelines are not appropriate for first-stage evaluation (Table 2). Across five components, we pose ten yes/no questions. A candidate species may be rejected by failure at any of the ten questions, or lack of information or high levels of uncertainty may trigger further analysis before reassessment. Some questions subsume several complex issues, but the intent is not to require exhaustive analysis. Rather, this is a 'first cut' to eliminate obviously unsuitable candidates. Those that do pass this first filter would be subject to more detailed assessment of feasibility and risk, along with planning for release and postrelease monitoring (Figure 1).

### *Past, current and future threats*

Releases should not take place until the cause of the original extinction or population decline is addressed. There may be irresolvable uncertainty over the relative importance of a range of causal factors in the case of prehistoric or poorly documented extinctions, in which case all possible threats, direct and indirect, biological, physical, social, political, and economic need to be considered. Although the original threats may no longer be relevant, new threats may have arisen in the period since extinction.

### Question 1: can the past cause(s) of decline and extinction be identified and addressed?

Even for recent and localized extinctions, the precise cause of declines may be obscure. The IUCN Guidelines acknowledge this uncertainty and do not close the door on further investigations, including carefully designed experimental releases to identify threats and limiting factors (Annex 3.2.10, [10]), providing all formal requirements have been met and the outcomes of releases will be monitored.

### Question 2: can potential current and future cause(s) of decline and extinction be identified and addressed?

Although the emphasis is necessarily on the identification and mitigation of the causes of the original extinction, it is also necessary to anticipate potential current and future threats to released animals, and to evaluate the feasibility of addressing these.

*Biological feasibility*

*Basic knowledge.* Information on the biology and ecology of the candidate species should be collated from available sources, including expert knowledge, oral histories, and traditional ecological knowledge. Knowledge of former distributions, social structure and behavior, diet, reproduction, parental care and growth, interspecific interactions, and biotic and abiotic habitat requirements is required. Where some uncertainty exists, as in the case of prehistoric population extinctions, valuable clues may be obtained from the biology and ecology of extant species that may be nearest living relatives or otherwise occupying a similar ecological niche (e.g., [22]).

**Question 3: are the biotic and abiotic needs of the candidate species sufficiently well understood to determine critical dependencies and to provide a basis for release area selection?**

This question subsumes all the information about the biology and ecology of the candidate species and is framed in terms of adequacy of information to enable the next, critical aspect, that of release area habitat, to be assessed.

*Release area habitat*

Selection of an appropriate release site (the point of release) and release area (the wider region within which released animals are expected to disperse and settle), *sensu* [23], is critical. Unsuitable release site habitat is a major cause of translocation failure [24], and releases with low chances of success might be considered 'cruel' [25]. Some general principles can be applied: for example, the longer the time since extinction, the less likely there is to be good information on habitat requirements; the greater the uncertainty over the ecological role and/or impact a resurrected species may have; and the greater the likelihood of significant habitat change within the indigenous range. Importantly, spatial and temporal change means that former distribution does not imply current suitability, past absence does not imply current unsuitability, and current suitability does not imply future suitability [21].

If suitable release habitat is too small in extent to support a restored population, is unavailable, unprotected, or subject to future changes due to human land use or climate change, then the technical undertaking of species DeExtinction with the intent to restore wild populations would be futile.

**Question 4: is there a sufficient area of suitable and appropriately managed habitat available now and in the future?**

This question combines the need to understand the habitat requirements of the focal species, with evaluation of the existence, extent, and status of suitable habitat currently and under realistic scenarios of changing climate and land-use patterns. One answer to this question could be 'maybe' if a suitable release area could be created following active restoration, improved management, or appropriate legal protection.

*Social feasibility*

*Policy and legislation.* Any conservation translocation must meet regulatory requirements relating to animal holding, movement and release, and veterinary requirements at appropriate levels (national, regional, and local) possibly requiring permission and approvals from multiple agencies [10]. As seems likely due to the technical demands of the DeExtinction process, animals will be resurrected in countries other than those containing their indigenous range, hence international agreements and conventions might apply. In addition, DeExtinction, by its nature, has implications for the classification of any members of a resurrected species that could influence how national policy regulates translocations. For example, Jones [20] cautions that the techniques used would mean resurrected animals would be genetically modified organisms (GMOs) and possibly subject to more than the usually stringent regulations concerning their transport, importation, and release.

**Question 5: is the proposed translocation compatible with existing policy and legislation?**

*Human concerns*

No conservation translocation can operate in disregard of stakeholders. Critically, human communities near the release area will have legitimate interests in the translocation, and success can be dependent on local community support. This is important where resurrected species have cultural, economic, or human health significance. The release of predatory species can be perceived as a threat to human life or livestock. By contrast, tangible benefits might accrue to having a resurrected species in the area, primarily through nature-based tourism, and this could be significant for economically challenged communities. Some communities might actively welcome the return of familiar species, but for others the extinction might have been too long ago for strong cultural links, or might have been viewed as reward for active persecution of an unwanted species. Conservation introductions will require careful preparation, because local communities might have had no previous experience with the resurrected species.

**Question 6: are the socioeconomic circumstances, community attitudes, values, motivations, expectations, and anticipated benefits and costs of the translocation likely to be acceptable for human communities in and around the release area?**

*Risk assessment*

Formal risk assessment entails evaluation of the probability of a given risk factor occurring and some estimate of its likely impact; the range of potential risks creates a 'risk landscape' [10]. For example, information on the biology, pathogens and parasites, and invasive potential of the candidate species needs to be considered. By incorporating risk within the decision process, such as in structured decision-making and adaptive management, it is possible to compare potential risks against potential benefits and weigh this against the risk attitudes of the relevant stakeholders (see [26,27] for detailed treatments). Risk or uncertainty might be too great to allow releases of resurrected species to take place, even if suitable habitat was available. Importantly, a transparent and structured

approach can enable good decisions to be made that reflect stakeholders risk attitudes.

*Ecological risk*

Ecological risk relates principally to the potential for harmful impacts on other species or on ecological processes within the release area. Processes to consider include: interspecific competition or predation, herbivory, and modification of habitat, food webs, and successional patterns [10]. Interspecific hybridization can result in the genetic-based extinction of extant species in recipient ecosystems, or of released species. Depending on the duration since extinction, species resurrection could potentially hybridize species that might have overlapped spatially in recipient habitats but been isolated temporally. The longer the time since extinction and the greater the subsequent habitat changes in the indigenous range, the greater the uncertainty concerning possible ecological risks. Conservation introductions outside the indigenous range, or the release of long-extinct species, carry a greater level of uncertainty, because these constitute creation of novel ecosystems [28], wherein the risks of ecological impacts will be more challenging to anticipate.

**Question 7: is there an acceptable risk of the translocated species having a negative impact on species, communities, or the ecosystem of the recipient area?**

This question combines many aspects and might seem too complex to answer with any certainty. Given that this is a coarse filter to eliminate patently unsuitable DeExtinction candidate species, it would be sufficient to rule out a subset of the most obvious risks, and conduct more in-depth risk assessment as part of detailed translocation planning.

*Disease risk*

Resurrected species might lack natural parasites and have no resistance to new pathogens encountered in the release area, placing the success of any restoration attempt at risk. Given that resurrection is likely to be in places remote from release sites, with periods of captive husbandry, there is risk of parasite co-introduction (source or transport hazards). In some, admittedly rare, cases, a population hazard at release sites might be known as a factor driving original species extinction and this will need to be removed or managed. A contemporary, non-DeExtinction, example of this includes attempts to establish populations of Tasmanian devils that are free of devil facial tumor disease [29]. The risk of ongoing population hazards and novel destination hazards requires extant reservoirs of the culprit pathogens. Disastrous outcomes for translocation success when release-site pathogens are encountered are well documented [30]. Risks posed by all hazards encountered on the translocation pathway can be assessed using disease risk analysis tools [31]. These tools offer a structured approach to defining disease risk associated with the release of any resurrected species. There can be high uncertainty in risk assignments with resurrected species and, if risk tolerance allows release of individuals, this should be factored into targeted postrelease monitoring to update risk assessments [32].

**Question 8: is there an acceptable risk of pathogen-related negative impacts to the resurrected species and the recipient system?**

*Socioeconomic risk*

Released species can pose direct risks by threatening human safety or livelihoods. Indirect effects can include impacts on ecosystem services, such as food availability, clean water, erosion control, pollination, or nutrient cycling. Unforeseen negative effects can cause financial and other social impacts that might lead to public opposition to the translocations [10], even where projects have commenced with local community support. Socioeconomic impacts in recipient ecosystems might be more difficult to predict for conservation translocations of resurrected than of extant species.

**Question 9: is there an acceptable risk of direct harmful impacts on humans and livelihoods, and indirect impacts on ecosystem services?**

*Reversibility*

Any translocation may not proceed as planned and failure to achieve project objectives must be considered as part of planning. The IUCN Guidelines stress the need for an exit strategy when investment of further resources is not justifiable. Here, we consider the specific case where harmful impacts or other unintended effects mean that free-ranging animals must be removed from the release area.

**Question 10: will it be possible to remove or destroy translocated individuals and/or their offspring from the release site or any wider area in the event of unacceptable ecological or socioeconomic impacts?**

It can be problematic to recapture and remove or destroy free-ranging animals if they have a low probability of detection, range more widely than anticipated, or occupy inaccessible areas.

## Case studies

We present three case studies of DeExtinction candidates (Boxes 1–3) that disappeared recently and which represent different continents, taxa, habitats, and extinction causes. The evaluation of these within our framework is not intended to be definitive; we have used the available published literature to model how, in general, the ten questions relating to translocation feasibility and risk might be approached to inform decision-makers on the feasibility of release for some proposed candidate species. A more detailed evaluation of candidates should include ecological information from all sources, including unpublished reports, and expert opinion, if such exist. Assessment of habitat availability, current and future threats, disease, and other risks should likewise incorporate the best available information from all sources. First-stage assessment of the suitability of a given DeExtinction candidate species applying these ten questions could take the form of a workshop bringing experts and available information together. If a candidate species clearly fails at one or more questions for which reliable information is available, less emphasis needs to be placed on addressing other questions for which detailed

**Box 1. Evaluation of the Yangtze River Dolphin (baiji) as a DeExtinction candidate**

The Yangtze river dolphin (*Lipotes vexillifer*) or baiji has an indigenous range that spans 1700 km of the middle and lower reaches of the Yangtze River and neighboring Qiantang River in China [34]. The last known sighting was in 2002, and the baiji was declared functionally extinct in 2006.

**Question 1: no**
Baiji populations declined as the increasing industrialization of China utilized the river for transportation, fishing, and hydroelectricity. Approximately 12% of the human population of the world lives along the Yangtze [35]. Threats include hunting, entanglement in fishing gear, collisions with vessels, habitat loss, and pollution [36]. Baiji have effective full legal protection against deliberate killing or harm throughout their range, but there is no effective protection from any other threat factor [36]. Efforts to improve habitat within reserves seem insufficient to meet the requirement that the cause of the original extinction has been addressed.

**Question 2: no**
Original threat factors remain in operation, with the exception of deliberate hunting. Industrial expansion and agricultural intensification along the Yangtze continues, with >15 billion $m^3$ of wastewater being discharged into the river annually, of which >12 billion $m^3$ is untreated waste [37].

**Question 3: yes**
The relatively recent extinction of baiji has given time for researchers to document its basic life-history characteristics, distribution, and ecology. Scientific studies of baiji ecology date back to 1980 [Chen *et al.* 1980 (in Chinese) cited in [34]].

**Question 4: (no)**
See Questions 1 and 2 above. In addition, although the Yangtze ecosystem is massively degraded and likely to become worse in the near future, the baiji recovery program advocated trying to establish an *ex-situ* breeding population in large protected oxbow lakes away from the main river channel, in which the major threats to baiji survival could be reduced or eliminated (Sam Turvey, pers. comm.). This approach was not implemented before it was too late, but one oxbow (Tian'e-zhou) supports a viable population of Yangtze finless porpoises, with an oxbow near Jianli, Hubei Province being developed for porpoise conservation. Such oxbows could provide suitable habitat for assisted colonization of a resurrected baiji, but this is uncertain. A precautionary approach would argue for rejection of baiji as a resurrection candidate in this 'first cut', but the potential for reassessment in the light of new information remains. The remaining questions are not addressed.

**Box 2. Evaluation of the Xerces blue butterfly as a DeExtinction candidate**

The Xerces blue butterfly (*Glaucopsyche xerces*) has an indigenous range that covers the San Francisco Peninsula, from Twin Peaks to North Beach, and Presidio on the Bay, south to Lake Merced. The butterfly was declared extinction in 1941 [38]. The information below is from [39] unless otherwise stated.

**Question 1: yes**
*Xerces* was limited to the San Francisco area, dependent on food plants of the genera *Lotus* and *Lupinus*. City expansion destroyed dune vegetation and, by 1941, the population occupied an area of only 21 m × 46 m. Habitat loss due to urban development caused its extinction, exacerbated by collecting. However, restoration of vegetated dune habitat could sustain *Xerces* populations, and collecting could be prevented within small reserves.

**Question 2: yes**
Providing that suitable dune habitat can be restored and protected, there are no significant new threats, although the effects of climate change on favored food plants remain unknown.

**Question 3: yes**
*Xerces* occupied sandy areas in association with patches of *Lotus scoparius* in well-drained soils in partial shade of Monterey cypress (*Cupressus macrocarpa*), and with beach lupine *Lupinus arboreus*, which served as host plants for oviposition and larval growth.

**Question 4: yes**
Much of the original prostrate dune habitat has been lost, but potentially suitable habitat remains within the 4.1-$km^2$ Golden Gate Park, which lies within the former distribution of the butterfly (http://www.golden-gate-park.com). However, the extent of food plants and their robustness to climate change needs confirmation. Successful translocation to San Francisco of the Mission blue butterfly (*Aricia icarioides missionensis*), a lycaenid butterfly also dependent on lupines (http://sfrecpark.org/parks-open-spaces/natural-areas-program/wild-habitat-conservation/), indicates that habitat for Xerces could be secured. Xerces larvae had a symbiotic relation with an unidentified ant species, which was lost following invasion by Argentine ants *Iridomyrmex humilis*. However, laboratory trials indicate that Xerces larval growth is possible without ants.

**Question 5: yes**
No specific policies have been found. Translocation of Mission blue butterflies to the San Francisco area took place under policy guidelines and provides a precedent for reintroduction of Xerces.

**Question 6: yes**
Xerces is the basis for the Xerces Society (http://www.xerces.org), a nonprofit organization dedicated to the protection of wildlife through conservation of invertebrates and their habitat. There is expected to be wide and sustained public support for efforts to reintroduce Xerces.

**Question 7: yes**
No negative impacts are anticipated.

**Question 8: unknown**
No harmful impacts anticipated.

**Question 9: yes**
No harmful impacts anticipated.

**Question 10: yes**
Xerces would occupy a limited area of dunes. Adults fly in a single brood in March–April, making them easy to collect in the unlikely event that any reintroduction would need to be reversed.

or reliable information may be lacking. The questions are set out in full in Table 3, and more detailed assessments are available as supplementary material online.

## Concluding remarks

Perceived benefits of DeExtinction include scientific knowledge, technological advancement, 'justice' in terms of correcting past human wrongs, 'wonder' in terms of restoring 'cool' species, and concrete environmental benefits. DeExtinction candidate lists tend to focus on a few iconic species [7,33], so-called 'charismatic necrofauna' (Alex Steffen, see http://www.salon.com/2013/09/06/de_extinction_wont_make_us_better_conservationists_partner/). Such species could be suitable candidates for restorations depending on the availability of suitable habitat and/or risks associated with failure, unexpected consequences of the translocation, impacts on human welfare and livelihoods, and impacts on the host ecosystem

**Box 3. Evaluation of the thylacine as a DeExtinction candidate**

The thylacine (*Thylacinus cynocephalus*) has an indigenous range that covers continental Australia, Tasmania, and New Guinea, although they occurred only in Tasmania by the time of European settlement. The last captive animal died in 1936. The information below is from [40], unless otherwise stated.

**Question 1: yes**
Human persecution drove to extinction populations that were already declining due to a reduced prey base, competition with feral dogs, and habitat fragmentation as a result of grazing [41].

**Question 2: yes**
A bounty system led to unsustainable harvest of the species. Although the prevention of hunting is possible, the effects of habitat fragmentation and interspecific competition remain uncertain.

**Question 3: yes**
Thylacine were moderately abundant across approximately half of Tasmania in areas of open dry or mixed forest, wetlands, and coastal heath, mainly in midland and eastern areas. Although locally heavily modified, large areas of habitat retain essential elements of food and shelter for thylacines.

**Question 4: yes**
Tasmanian devils (*Sarcophilus harrisii*) occupy the same area preferred by thylacine, with densities highest in the dry and mixed sclerophyll forests in the eastern half and northwest coast (http://www.dipw.tas.gov.au). Habitat is relatively intact and able to support devil populations. By 2003, 95% of the 1.9 million ha of high-quality wilderness on Tasmania was within reserves (http://www.rpdc.tas.gov.au/soer). However, the impact of possible spread of red fox (*Vulpes vulpes*) is unknown.

**Question 5: yes**
There is a 1999 Federal Policy for the translocation of threatened animals in Australia. The Tasmanian Government has a policy for the translocation of native animals (http://www.tas.gov.au) prompted by the translocation of Tasmanian devils.

**Question 6: (yes)**
This is likely to be 'yes' in light of the general public support for the Tasmanian devil, a species once also considered an agricultural threat. Although some landowners might resist re-establishment, the thylacine is distinctively Tasmanian and stewardship could be fostered. There could be significant income generation from nature-based tourism.

**Question 7: (yes)**
Thylacine occupied a specific niche as an exclusively carnivorous predator of small animals within woodland and heath areas, hunting solitarily or in small groups. An adequate prey base exists. Impacts would likely act upon, rather than arise from, thylacine.

**Question 8: unknown**
A flea, tapeworm, and roundworm have been recorded from thylacine, and the flea *Uropsylla tasmanica* occurs on members of the family Dasyuridae.

**Question 9: yes**
Original extinction through persecution was driven by threats to livestock; therefore, sheep kills would have to be addressed by compensation packages.

**Question 10: yes**
Thylacine existed at low densities in defined areas. In the same way that past harvest was possible, control of thylacine would be feasible.

If the aim of DeExtinction is restoration of viable free-ranging populations for conservation benefit, and it should be, then the technical ability to resurrect appropriate individuals is insufficient grounds for selection of a candidate species. Planning the resurrection of species should be preceded by clearly stated conservation goals, and an assessment of translocation suitability. Early translocation planning might eliminate several high-profile candidate

**Table 3. Summary of DeExtinction candidate species case study evaluations**

| Question | Candidate species[a] | | |
|---|---|---|---|
| | *Lipotes vexillifer* (baiji) | *Glaucopsyche xerces* (Xerces blue) | *Thylacinus cynocephalus* (thylacine) |
| 1. Can the past and future cause(s) of extinction be identified and addressed? | No | Yes | Yes |
| 2. Can potential current and future cause(s) of decline and extinction be identified and addressed? | No | Yes | Yes |
| 3. Are the biotic and abiotic needs of the candidate species sufficiently well understood to determine critical dependencies and to provide a basis for release area selection? | Yes | Yes | Yes |
| 4. Is there a sufficient area of suitable and appropriately managed habitat available now and in the future? | (No) | Yes | Yes |
| 5. Is the proposed translocation compatible with existing policy and legislation? | – | Yes | Yes |
| 6. Are the socioeconomic circumstances, community attitudes, values, motivations, expectations, and anticipated benefits and costs of the translocation likely to be acceptable for human communities in and around the release area? | – | Yes | (Yes) |
| 7. Is there an acceptable risk of the translocated species having a negative impact on species, communities, or the ecosystem of the recipient area? | – | Yes | (Yes) |
| 8. Is there an acceptable risk of pathogen-related negative impacts to the resurrected species and the recipient system? | – | ? | ? |
| 9. Is there an acceptable risk of direct harmful impacts on humans and livelihoods, and indirect impacts on ecosystem services? | – | Yes | Yes |
| 10. Will it be possible to remove or destroy translocated individuals and/or their offspring from the release site or any wider area in the event of unacceptable ecological or socioeconomic impacts? | – | Yes | Yes |
| Potentially acceptable DeExtinction candidate species for further assessment | No | Yes | Yes |

[a]( ), provisional answer; –, not addressed;?, unknown at this time but assumed not to be a critical component necessitating early rejection of a candidate species.

species and, thus, avoid time, expense, animal welfare concerns, and the raising of false public expectations.

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## Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.tree.2014.01.007.

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